Effects of competition on growth of Amur linden plantation

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Abstract: Competition is the common ecological phenomenon that exists in a stand after canopy closure. The effect of competition on DBH, height, crown diameter and crown area of individual amur linden trees was examined. We used two plots data, from amur linden (*Tilia amurensis*) plantation, 14 years old, in Liaoning province, to analyze the correlations among DBH, total height, crown diameer and crown area, and used the size-ratio of competiting tree DBHs to subject tree DBH to calculate distance-dependent competition index. The results show that DBH has the largest variation comparing with standard deviations and coeficeints. DBH and crown factors have higher correlations. Competition index is an important factor in tree growth. The best fitting models are exponent, for CI vs height and CI vs crown factors, and power, for CI vs DBH. The more closed correlation model is CI vs DBH (R^2=0.7028), which performed 16.32%-18.86% better than other models. These reflect that DBH is an important indicator to display stand competition for amur linden.

Key Wards: Competition; Growth correlation; Amur linden; Plantation
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Introduction

Competition or interference is important in forest growth and stand structure (Weiner 1982,1984). For example, the size of individual crowns and diameters is affected by competition. Most interference studies have focused on the mean performance of plants in relation to density (Harper 1977) and neighbouring distance (Martin *et al.* 1977; Weiner 1984; Biging *et al.* 1992). They used distance-dependent competition indices (CI) to describe influence for individual trees that includes all competitors in the zone of influence and provide better correlations with tree growth (Daniels *et al.* 1986; Biging *et al.* 1992). Biging *et al.* (1992) divided distance-dependent competition indices into three groups: (1)size-ratio; (2)crown or influence-zone overlap; (3)growing space. In this paper, we addresses distance-dependent indices with size-ratio, which calculate from the sums of ratios of subject tree dimensions to competitor tree dimensions. These ratios are weighted by distances of the subject tree to its competitors. Diameter at breast height(DBH), total height, and basal area, as also as biomass, are common tree dimensions used. The CI which is based on the ratios of competiting tree DBHs to subject tree DBH has the highest correlation with measured growth evaluated on a single set of lots for conifer species(Biging *et al.* 1992).

Amur linden (*Tilia amurensis*) is a commercial hardwood species in Northeast China. There are many site factors, e.g., slope degrees, aspects, soil types, microsite conditions, influence the plantation growth of amur linden. But competition among trees within a stand exists when resource availability falls below the sum requirement of the population for optimal growth (Brand *et al.* 1988; Biging *et al.* 1992). The relationships of CI with DBH, height, crown diameter and crown area, are important issues to develop models for predicting tree growth (Tome *et al.* 1989). The objective of this study are: (1) to calculate competition index, which is based on the ratios of competiting tree DBHs to subject tree DBH, (2) to compare the relationships of CI with DBH, height, crown diameter and crown area.

Study method

Site

Study site was located at the Wandianzi Experiment Farm (WEF), (E125°18', N41°50'), in east of Liaoning Province. This site is in the Changbai Mountain range, average elevation is about 500 m, the highest is over 800 m. The climate of WEF is

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terrestrial temperature and monsoon climate. Annual mean temperature is 4.2℃, ranging from −37.5℃ to 35.8℃, and annual accumulated temperature(≥5℃) is about 3 100℃. Annual precipitation is from 714 mm to 1 055 mm. The frost-free days are about 125 d. The typical mountain earth is dark brown forest soil. Most land area in WEF are second forests after old growth forests were harvested in many years ago, and plantations with different coniferous species and hardwoods, e.g., Korea pine (*Pinus Koraiensis*), larch (*Larix gmilini, Larix olgensis*) amur linden (*Tilia amuriensis*) and Manchurian ash (*Fraxinus manshurica*)

Plots survey

Tow plots, 15 mx20 m (plot 1) and 15 mx40 m (plot 2), for this study are located in plantation of amur linden which was planted in 1984, with plant and row spacing of 1.5 mx1.5 m. The plots were close each other at elevation of 610 m. Soil depth is 56 cm, pH value 6.0, and slope degree is 18°. Every plot was stem-mapped, and DBH, total height, crown length, crown diameter were recorded for trees.

Calculation of competition index

The formulas to calculate distance-dependent competition indices use variable for size and dimensions of subject trees and assumed competitors and distances between them (Biging *et al.* 1992). The value of the CI for each individual tree depends upon the formulation of the relationship between the chosen variables as well as on the method used to define neighbor trees as competitors. In a stand, any tree would be subject trees or competitive trees. We define the nearest neighbors to subject tree as competitors, and the zone of influence or effect radius of competition is defined by the size of distance between subject tree and neighbors. Size-ratio indices calculated sums of ratios of subject tree dimensions to competitor tree dimensions. The most common tree dimensions used are DBH (Hegyi 1974, Martin *et al.* 1984) in the calculation of the CI. The equations for CI is:

$$CI = \sum (D_j D_i^{-1}) dist_{ij}^{-1} \quad (1)$$

Where CI_j is value of competition index for an individual tree; D_j is diameter at breast height of object tree (j); D_i is diameter at breast height of competitors (i); and $dist_{ij}$ is the distance between subject tree (j) and competitors (i).

Calculation of individual growth

For each plot, the mean and standard deviation of diameters, total height, crown length, crown diameters, and crown area were calculated, and then regression is used to fit models between CI and individual growth values. The fitting models are:

$$Y=aX+b \quad (2)$$
$$Y=ae^{bX} \quad (3)$$
$$Y=aX^{b} \quad (4)$$
$$Y=a\ln X+b \quad (5)$$

Where Y is individual growth factors of diameters, height, crown length, crown diameters, crown area; X is competition index, a, b are constants.

Results

Variations and correlations among individual trees

Comparing the forest land, the plot condition could be a homogenous, but the growth variations are significantly due to competition in trees, see Table 1. The coefficients of variation of diameter are the larger than any growth factors in both plots, the followed by crown area, both have a close correlation, see Table 2. The values of DBH and crown area indicate that the size of tree in stands are different though they were planted in same time.

Table 1. Means and standard deviations of individual growth of amur linden

		DBH(cm)	Height (m)	Crown-d(m)	Crown-a(m^2)	CI	Samples
Plot1	mean	6.74	5.73	2.18	3.73	10.27	56
	Std	2.53	1.31	0.64	1.63	5.89	
	Cv%	94.86	30.22	18.99	67.76	338.46	
Plot2	mean	5.62	5.32	2.05	3.29	11.98	166
	Std	1.91	0.97	0.60	1.38	5.82	
	Cv%	64.92	18.02	17.70	57.87	282.30	

A small size of tree occupies a small space and resource (Weiner 1984; Biging *et al.* 1992; Schwinning *et al.* 1998), and would have a little ability in competition. Because CI was calculated by the size-ratio of subject tree DBH to competitor tree DBHs (equation (1)), the coefficients of variation of

CI reflect that competition ability of trees in plots are quite different, and their range distributions are from 1.82 to 26.73 (plot 1) and from 3.11 to 34.87 (plot 2) respectively.

Table 2. Correlation matrix among factors in both plots of amur linden

	DBH	Height	Crown-d	Crown-a	DBH	Height	Crown-d	Crown-a
		Plot 1					Plot 2	
DBH	1				1			
Height	0.770	1			0.835	1		
Crown-d	0.825	0.670	1		0.844	0.746	1	
Crown-a	0.805	0.625	0.990	1	0.818	0.688	0.978	1

Relations of CI among individual growth

The sizes of DBH, height, crown diameter, crown area and crown volume are close with CI, (see Fig 1). The best fitting models are exponent model(equation (3)), for CI vs height and CI vs crown factors(e.g., crown diameter, crown area and crown volume) and power model(equation(4)), for CI vs DBH, comparing with other, e.g., linear (equation (2))and logarithm(equation(5)) models. There have higher significant correlations ($p<0.01$) among the fitting models. The more closed correlation is CI vs DBH ($R^2=0.7028$), which performed 16.32-18.86% better than other models. This reflects the higher diameter growth variability of amur linden with competitions. One possible explanation is that DBH is a more sensitive factor in competition than crown factors due to crown growth plasticity through DBH has a close correlation with crown.

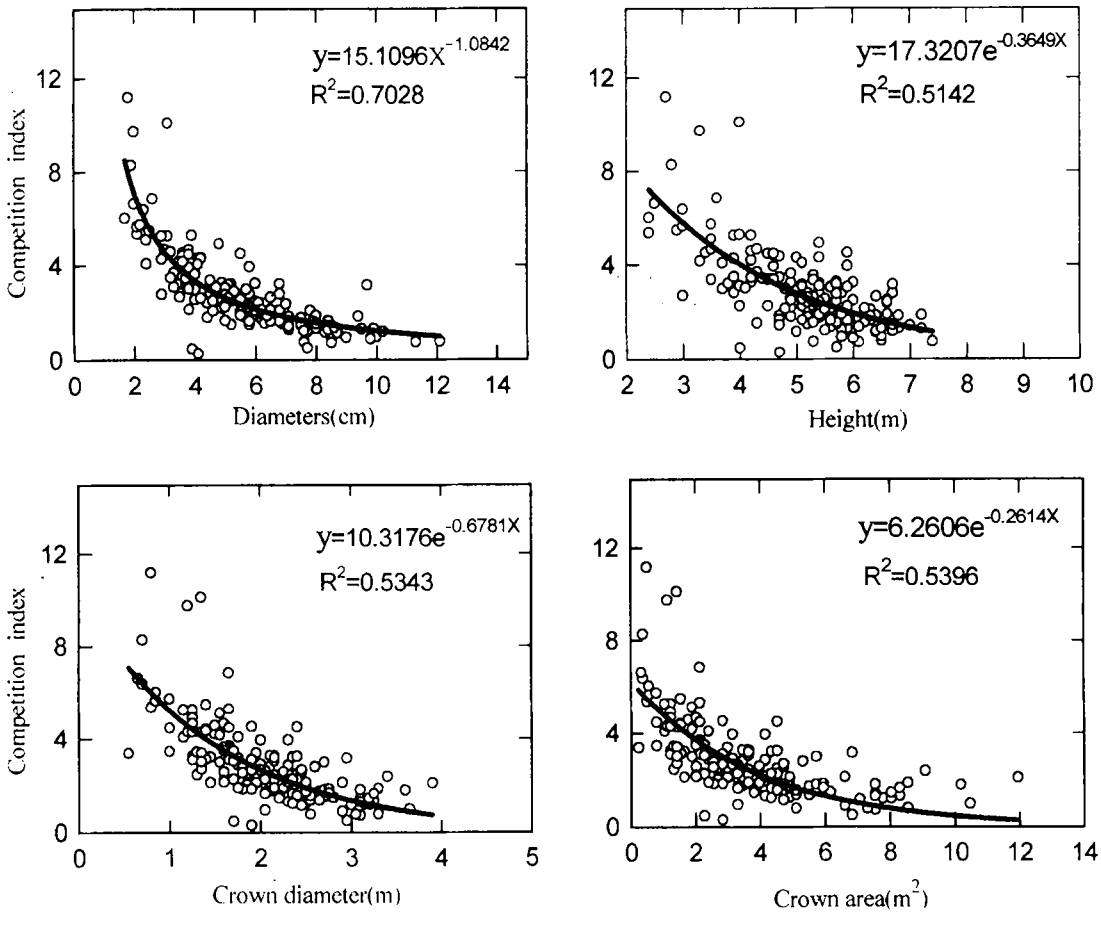

Fig 1. Effects of competition on diameter (a), height (b), crown diameter (c) and crown area (d) in amur linden young stands.

Discussion

In this study, the total size of the neighbors within zone of a subject tree was clearly the most important factor in determining the differences in individual growth rates, the distance of neighbors was also important (Weiner 1984). Amur linden is a hardwood species, the site condition and herbaceous were the main factors that influenced small young tree growth after planting a few years. Competition for both aboveground and belowground resources took place between small young trees and herbaceous. Aboveground competition is concentrated within the area occupied by individual crowns, belowground competition or root competition is from tree root and herb root interactions for soil water and nutrients. After canopy closure, competition took place among the trees.

A small tree of amur linden, i.e., small DBH, little height, small crown size, would have a larger competition impact, and small competition ability, a larger neighbor has stronger influence to subject tree than small neighbors. Therefor, CI is an index, which not only indicate the competition ability, but also indicate tree size indirectly. CI, to be as an impact factor, can limited tree growth, and has a negative relation with DBH, height and crown-d and crown-a (Fig 1).

In a stand, growth models based on the paradigm the growth is equal to potential growth, assuming a free to grow tree, reduced by competition (Wensel *et al.* 1987; Biging *et al.* 1992). We can use the relationships among CI and tree factors, e.g., DBH, height, Crown-d and crown-a to develop potential growth models and to predict amur linden growth. The growth of individual tree or a stand is a process, CI should be changed with time, and a perfect growth model should consider both growth process and competition process.

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